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*Original Research*

# Comparative analysis of the relationship between bioelectrical impedance analysis results and laboratory data

Relationship between bioelectrical impedance analysis and laboratory results

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**Abstract**

Aim: In this study, we aimed to assess the relationship between demographic and laboratory data and bioelectrical impedance analysis (BIA) results in patients <40 and ≥40 years of age.

Material and Methods: This cross-sectional study was conducted at Ayancık State Hospital, Internal Medicine Clinic, Sinop, Turkey. This study was performed using data derived from the medical files of 674 adult patients (545 females, 129 males) with an average age of 40.15 ± 8.60 years.

Results: In patients <40 years of age, there was a moderate relationship between inbody PUM and body fat percentage (r=0.489), inbody PUM and BMI (r=-0.626), inbody PUM and fat mass (r=-0.453), BMI and body fat percentage (r=0.489), and BMI and fat mass (r=0.637). In patients aged ≥ 40 years, a strong relationship was noted between fat mass and serum glucose level (r=0.851) and body fat percentage and serum LDL levels (r=0.784). A moderate relationship was observed between fat mass and platelet count (r=0.471), fat mass and BMI (r=0.581), fat mass and body fat percentage (r=0.470), fat mass and inbody PUM (r=-0.494), inbody PUM and body fat percentage (r=-0.670), body fat percentage and fat mass (r=0.510), and body fat percentage and BMI (r=0.503).

Discussion: We suggest that BIA may provide important implications for the management of patients with obesity and metabolic disorders.

**Keywords**

Bioelectrical Impedance Analysis, Obesity, Fat Mass, Inflammation, Marker

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## Introduction

It has been proven that as people get older, their body composition changes, even if their weight does not change. According to studies, as people get older, their fat mass grows while their muscle mass declines. However, the cause of such modifications remains unknown. There is some evidence that individual organ metabolic rates are lower in elderly people than in younger people. We infer that the mass of the single organ/tissue decreases with age, as does the metabolic rate of some organs, resulting in a decrease of the metabolic rate at rest, favoring changes in body composition that contribute to an increase in fat mass (FM) and decrease in lean mass (LM) [1]. Body composition alterations have long been linked to aging and are physiologically undesirable. With age, fat accumulation and LM loss are significant alterations. The pattern and rate of age-related changes in body composition are often affected by a range of factors, including gender, ethnicity, level of physical activity, and calorie intake. Anthropometric measurements involve body mass index (BMI), abdominal waist circumference, and skinfold measurements. These measurements are rapid and low-cost. However, they have substantial flaws, such as a lack of consistency among techniques and the potential for measurement errors when measuring waist circumference and skinfold [2].

Due to the diversity of ethnicities, there are no common cutoff thresholds for waist circumference. More importantly, BMI, weight, and height alone are unable to distinguish between lean mass (LM) and fat mass (FM), as well as subcutaneous and visceral fat. Another indirect technique for the evaluation of the composition of the body is bioelectrical impedance analysis (BIA).

This approach is noninvasive and safe, and the equipment is portable, so it can be used in an ambulatory setting. The resistance of the body as a conductor of an electrical current, FM, and fat-free mass (FFM), where FFM is a charge conductor and FM is a non-conductor, are used by BIA to estimate total body water [2].

The investigation of body composition is important for understanding human energy and protein metabolism due to strategies for the measurement of energy stores and protein content. The balance between energy and protein can be observed over time, and the relationship between dynamic measures of energy and protein metabolism can be assessed via inter-individual comparisons [3].

The link between the distribution of abdominal fat and inflammatory markers is a hot topic. The leukocyte count was positively related to abdominal obesity in female obese teenagers, and this connection was stronger for subcutaneous adiposity compared to visceral adiposity [4].

Our purpose was to evaluate the relationship between hematological, biochemical, and inflammatory parameters and bioelectrical impedance analysis results in patients <40 and ≥40 years of age.

## Material and Methods

### *Study design*

This cross-sectional study was carried out in the internal medicine clinic of a state hospital between 29 November 2021-13 December 2021. The medical files of 674 adult patients (545 females, 80.1%; 129 males, 19.1%) were reviewed. The average age was 40.15 ± 8.60 years (range: 18 to 80). Demographic and clinical data consistent with age, sex, complete blood count, and serum biochemistry results as well as BIA results were extracted from the hospital database. The ethics committee approval was obtained before the study (date/no: E-71522473-050.01.04-83550-530).

Simple, quick, and reliable body composition measures are commonly necessary for medical and nutritional follow-up. Consequently, in research laboratories, hospitals, private clinics, and wellness centers, BIA constitutes a standard tool for the analysis of body composition over an extent of age and body weight [5]. Using a digital console, the subject's sex, age, and height are manually written into the instrument, and the subject's fat mass (FM) or percent FM is displayed instantly.

Patients were measured for body weight and height while wearing light clothing and not wearing shoes. The BMI was calculated by dividing the weight by the square of the height ($kg/m^2$).

Blood samples were received from a peripheral vein early in the morning after an overnight fast of 8 hours. Blood samples were collected and examined on the same day using commercially available vacuum tubes. Serum biochemical parameters were measured using an autoanalyzer (Hitachi 747 autoanalyzer, Tokyo, Japan). The results of the total blood count were determined using an autoanalyzer (Sysmex XE-2100, Kobe, Japan).

### *Bioimpedance analysis*

Within the field, the BIA method is commonly utilized to calculate LM, FM, and body fat percentage. In BIA devices, which produce a single frequency alternating current, a pair of collector electrodes assess the voltage decrease over a measured tissue bed [6].

A component of age is included in almost all published comprehensive BIA prediction systems. Because age-related effects are so significant, any new BIA descriptive component prediction models must be constructed and cross-validated in the elderly before being employed in this group [3].

The device used to measure the impedance value was a multifrequency electrical impedance analyzer (Inbody S20, Korea) with a frequency range of 1 kHz to 1 MHz and an 800A steady electrical stream through the body. The entire procedure took less than 2 minutes. All data were saved in the instrument and automatically processed by computer software. Lean mass (LM), FM, body fat percentage, and in body PUM were collected as body composition data.

### *Statistical analysis*

The means, standard deviation, and range were utilized to present all descriptive statistical results. The Kolmogorov-Smirnov test was utilized to test the normal distribution of all variables. Since all variables were non-homogeneous, comparisons were carried out with the Mann-Whitney U test, and expressed as median, minimum, and maximum. Categorical variables were tested with the Chi-square test. Pearson's correlation analysis was used to examine the correlation between variables. Statistical Package for Social Sciences version 12.0 was used for all calculations (SPSS Inc., Chicago,

IL, USA). The level of significance was set at a p-value of <0.05.

*Outcome parameters*

All subjects underwent a complete medical evaluation, including the measurement of anthropometric parameters such as weight and height per standardized methods routinely performed within the outpatient clinic of our hospital's internal medicine department. Complete blood count, as well as serum biochemical analysis, were performed. Furthermore, BIA was performed utilizing the Inbody S20 device, (Inbody S20, Korea). Correlation was sought between LM, FM, body fat percentage, Inbody PUM and WBC count, hemoglobin level, lymphocyte, neutrophil, monocyte, and platelet counts, red cell distribution width, mean platelet volume, mean corpuscular volume, serum levels of glucose, urea, creatinine, aspartate transaminase (AST), alanine transaminase (ALT), and triglycerides.

The r value and strength of correlation were interpreted as follows: 0.00-0.19: very weak; 0.20-0.39: weak; 0.40-0.69: moderate; 0.70-0.89: strong; 0.90-1.00: very strong.

## Results

Our study population consisted of 674 patients (545 females, 80.1%; 129 males, 19.1%) with an average age of 40.15 ± 8.60 years (range: 18 to 80). Of 674 patients, 354 (%52.5) were younger than 40; while 320 cases (%47.5) were aged ≥40. An overview of demographic and clinical characteristics of patients <40 and ≥40 years of age is presented in Table 1.

Table 2 demonstrates the correlation analysis results between BIA results including lean mass, fat mass, inbody PUM, and body fat percentage, and laboratory markers, including hematological and biochemical results in patients younger than the age of 40. There was a moderate relationship between inbody PUM and body fat percentage (r=0.489), inbody PUM and BMI (r=-0.626), inbody PUM and FM (r=-0.453). In the same age group, there was a moderate link between BMI and body fat percentage (r=0.489) and BMI and FM (r=0.637).

On the other hand, the association between BIA results and demographic and laboratory parameters under investigation in patients aged ≥ 40 is shown in Table 3. In this group, there was a strong association between FM and serum glucose level (r=0.851), while a moderate association was observed between FM and platelet count (r=0.471), FM and BMI (r=0.581), FM and body fat percentage (r=0.470), and fat mass and inbody PUM (r=-0.494). Similarly, there was a moderate relationship between inbody PUM and body fat percentage (r=-0.670). Notably, there was a strong relationship between body fat percentage and serum LDL levels (r=0.784). A moderate relationship was noted between body fat percentage and FM (r=0.510) as well as between body fat percentage and BMI (r=0.503).

**Table 1.** Characteristics of patients aged <40 and ≥40 years of age (n=674).

| Variable | | Age group | | T-value | p-value |
|---|---|---|---|---|---|
| | | <40 years | ≥40 years | | |
| Sex | Female | 286 | 259 | | |
| | Male | 68 | 61 | | |
| Age (years) | | 26.99 ± 8.42 | 54.28 ± 8.87 | 40.857.248 | <0.001 |
| Height (cm) | | 165.33 ±15.48 | 160.06 ± 8.55 | 5.538.577 | <0.001 |
| Weight (kg) | | 83.53 ± 17.74 | 78.35 ± 14.85 | -3.995.044 | <0.001 |
| Lean mass (kg) | | 26.17 ± 6.42 | 28.69 ± 18.30 | 2.336.780 | 0.001 |
| Fat mass (kg) | | 30.36 ±12.24 | 39.85 ± 14.05 | 9.305.279 | <0.001 |
| Body mass index (kg/m$^2$) | | 29.47 ± 6.24 | 31.29 ±7.91 | 3.292.703 | <0.001 |
| Body fat percentage (%) | | 44.30 ± 8.10 | 54.51 ± 7.90 | 16.554.744 | <0.001 |
| Inbody PUM | | 64.51 ± 10.16 | 61.33 ±9.26 | -4.251.128 | <0.001 |
| WBC count (x10$^3$/mL) | | 7.38 ± 1.91 | 6.84 ±1.82 | -3.757.199 | <0.001 |
| Hemoglobin level (g/dL) | | 14.16 ± 4.28 | 13.19 ± 2.57 | -3.605.295 | 0.001 |
| Platelet count (cells/µL) | | 261.989 ± 67.370 | 237.619 ± 59.992 | -4.967.449 | <0.001 |
| Red cell distribution width (%) | | 17.32 ± 10.88 | 17.06 ± 9.13 | -0.3371 | 0.368 |
| Lymphocyte count (cells/µL) | | 2.66 ± 1.63 | 2.18 ± 1.10 | -4.518.136 | <0.001 |
| Neutrophil count (cells/mL) | | 5.50 ± 3.57 | 4.85 ± 2.93 | -2.593.156 | 0.005 |
| MCV (femtolitre) | | 83.92 ± 5.59 | 85.10 ± 8.76 | 2.060.129 | 0.02 |
| MPV (femtolitre) | | 9.36 ± 0.98 | 9.56 ± 1.12 | 2.455.699 | 0.007 |
| Monocyte count (x10$^3$/mL) | | 0.78 ± 0.97 | 0.85 ± 1.10 | 0.872335 | 0.191 |
| Glucose (mmol/L) | | 96.83 ± 24.59 | 121.34 ± 38.00 | 9.827.139 | <0.001 |
| Urea (mg/dL) | | 21.88 ± 5.88 | 29.81 ± 13.58 | 9.659.468 | <0.001 |
| Creatinine (mg/dL) | | 0.70 ± 0.28 | 0.83 ± 0.40 | 4.839.879 | <0.001 |
| AST (U/L) | | 19.09 ± 9.00 | 21.23 ± 9.49 | 2.995.861 | 0.001 |
| ALT (U/L) | | 22.29 ± 22.14 | 25.18 ± 15.45 | 1.979.901 | 0.02 |
| HDL (mg/dL) | | 64.43 ± 30.24 | 52.13 ± 20.18 | -6.263.932 | <0.001 |
| LDL (mg/dL) | | 106.47 ± 46.26 | 132. 238 ± 56.03 | 6.471.254 | <0.001 |
| Triglyceride (mg/dL) | | 115.65 ± 69.84 | 152.17 ± 90.19 | 5.833.085 | <0.001 |

(Abbreviations: AST: aspartate transaminase; ALT: alanine transaminase, LDL: low-density lipoprotein; HDL: high-density lipoprotein; MPV: mean platelet volume; MCV: mean corpuscular volume; WBC: white blood cell count, Inbody PUM).

**Table 2.** Correlation between, demographic, hematological, biochemical variables and bioelectrical impedance analysis results in patients <40 years of age.

| Variable | | Lean mass | Fat mass | Inbody PUM | Body fat percentage |
|---|---|---|---|---|---|
| Age | p | <0.001 | <0.001 | <0.001 | <0.001 |
| | r | 0.115 | 0.223 | -0.166 | 0.158 |
| Weight | p | <0.001 | <0.001 | <0.001 | <0.001 |
| | r | 0.173 | 0.262 | -0.227 | 0.170 |
| Lean mass | p | - | <0.001 | 0.970 | 0.579 |
| | r | - | 0.153 | 0.001 | 0.016 |
| Fat mass | p | <0.001 | - | <0.001 | <0.001 |
| | r | 0.151 | - | -0.451 | 0.359 |
| Inbody PUM | p | 0.970 | <0.001 | - | <0.001 |
| | r | 0.001 | -0.451 | - | -0.438 |
| Body fat percentage | p | 0.579 | <0.001 | <0.001 | - |
| | r | 0.016 | 0.359 | -0.438 | - |
| Body-mass index | p | <0.001 | <0.001 | <0.001 | <0.001 |
| | r | 0.239 | 0.637 | -0.626 | 0.489 |
| WBC count | p | 0.435 | 0.033 | 0.001 | 0.008 |
| | r | 0.024 | 0.064 | -0.099 | 0.080 |
| Platelet count | p | 0.018 | 0.220 | <0.001 | 0.001 |
| | r | -0.073 | 0.037 | -0.111 | 0.100 |
| MCV | p | 0.460 | 0.456 | 0.049 | 0.057 |
| | r | 0.022 | -0.023 | 0.060 | -0.058 |
| MPV | p | 0.700 | 0.021 | 0.580 | 0.506 |
| | r | 0.012 | 0.070 | -0.017 | 0.020 |
| Glucose | p | 0.046 | <0.001 | 0.002 | 0.015 |
| | r | 0.060 | 0.174 | -0.094 | 0.079 |
| LDL | p | 0.028 | 0.047 | 0.337 | 0.020 |
| | r | 0.070 | 0.064 | -0.031 | 0.035 |
| Triglycerides | p | <0.001 | <0.001 | 0.019 | 0.003 |
| | r | 0.138 | 0.131 | -0.075 | 0.095 |
| Urea | p | 0.405 | 0.031 | 0.006 | 0.044 |
| | r | 0.025 | 0.065 | -0.084 | 0.062 |
| Creatinine | p | 0.442 | 0.931 | 0.929 | 0.725 |
| | r | 0.023 | -0.003 | -0.003 | -0.011 |
| AST | p | 0.074 | 0.067 | 0.020 | 0.591 |
| | r | 0.055 | 0.056 | -0.071 | 0.057 |
| ALT | p | <0.001 | <0.001 | 0.010 | 0.486 |
| | r | 0.150 | 0.109 | -0.079 | 0.021 |
| HDL | p | 0.493 | 0.608 | 0.505 | 0.965 |
| | r | -0.022 | -0.016 | 0.021 | -0.001 |

(Abbreviations: AST: aspartate transaminase; ALT: alanine transaminase, LDL: low-density lipoprotein; HDL: high-density lipoprotein; MPV: mean platelet volume; MCV: mean corpuscular volume; WBC: white blood cell count, Inbody PUM)

**Table 3.** The correlation between, demographic, hematological, biochemical variables and bioelectrical impedance analysis results in patients ≥ 40 years of age.

| Variable | | Lean mass | Fat mass | Inbody PUM | Body fat percentage |
|---|---|---|---|---|---|
| Age | p | 0.844 | 0.222 | 0.001 | 0.874 |
| | r | -0.009 | 0.054 | -0.146 | 0.116 |
| Weight | p | 0.279 | <0.001 | <0.001 | 0.007 |
| | r | 0.048 | 0.212 | -0.246 | 0.307 |
| Lean mass | p | - | <0.001 | 0.615 | 0.973 |
| | r | - | 0.118 | 0.022 | 0.104 |
| Fat mass | p | 0.118 | - | <0.001 | <0.001 |
| | r | 0.070 | - | -0.494 | 0.510 |
| Inbody PUM | p | 0.615 | <0.001 | - | <0.001 |
| | r | 0.022 | -0.494 | - | -0.341 |
| Body fat percentage | p | <0.001 | <0.001 | <0.001 | - |
| | r | 0.041 | 0.470 | -0.670 | - |
| Body-mass index | p | 0.020 | <0.001 | <0.001 | <0.001 |
| | r | 0.022 | 0.581 | 1 | 0.503 |
| WBC count | p | 0.980 | 0.611 | 0.294 | 0.221 |
| | r | -0.061 | 0.023 | -0.048 | 0.056 |
| Platelet count | p | 0.388 | 0.033 | 0.032 | 0.013 |
| | r | -0.040 | 0.471 | -0.098 | 0.113 |
| MCV | p | 0.041 | 0.451 | <0.001 | 0.047 |
| | r | 0.106 | -0.311 | 0.055 | 0.206 |
| MPV | p | 0.923 | 0.098 | 0.658 | 0.305 |
| | r | -0.004 | 0.076 | -0.020 | 0.047 |
| Glucose | p | 0.831 | 0.139 | 0.514 | 0.056 |
| | r | 0.010 | 0.851 | -0.030 | 0.011 |
| LDL | p | 0.974 | 0.643 | 0.688 | 0.001 |
| | r | 0.002 | -0.009 | -0.088 | 0.784 |
| Triglycerides | p | 0.084 | 0.235 | 0.637 | 0.989 |
| | r | 0.032 | 0.056 | -0.022 | 0.082 |
| Urea | p | 0.661 | 0.325 | 0.009 | 0.332 |
| | r | -0.020 | 0.045 | -0.120 | 0.045 |
| Creatinine | p | 0.789 | 0.520 | 0.669 | 0.643 |
| | r | 0.012 | -0.026 | 0.020 | -0.021 |
| AST | p | 0.724 | 0.172 | 0.182 | 0.853 |
| | r | 0.029 | 0.063 | -0.062 | 0.009 |
| ALT | p | 0.088 | 0.022 | 0.246 | 0.840 |
| | r | 0.102 | 0.106 | -0.054 | -0.009 |
| HDL | p | 0.113 | 0.343 | 0.443 | 0.933 |
| | r | -0.075 | -0.045 | 0.036 | -0.063 |

(Abbreviations: AST: aspartate transaminase; ALT: alanine transaminase, LDL: low-density lipoprotein; HDL: high-density lipoprotein; MPV: mean platelet volume; MCV: mean corpuscular volume; WBC: white blood cell count, Inbody PUM)

## Discussion

In this study, we investigated the link between BIA results and serum hematological and biochemical parameters in patients <40 and ≥40 years of age. Our results yielded that BIA may provide important metabolic and clinical clues for obesity and other inflammatory disorders and comorbidities in patients of different age groups. The interpretation of findings derived from BIA together with laboratory data may help tailor the treatment plan in clinical practice.

The body fat distribution may aid in the determination of the risk of cardiovascular disease and for the prophylaxis and therapy of metabolic disorders associated with obesity. Adipose tissue not only regulates lipid and glucose metabolism, but also has an active endocrine function. Adipocytes, immune system cells, and endothelium secrete bioactive substances that arrange metabolic and inflammatory reactions [7].

Triglyceride increases the lipid droplet size in adipocytes, causing obesity. It also causes adipokine synthesis and secretion to be disrupted, which has been linked to obesity-induced inflammation and insulin resistance. Inflammation and insulin resistance both participate in the occurrence of metabolic complications of obesity which subsequently result in a higher rate of mortality [8].

The anatomic position of adipose tissue is pivotal for health,

life expectancy, and the predisposition to various diseases [9]. BMI is a widely used metric for determining nutritional status [7]. BMI assessment, on the other hand, is not gender-specific and has destitute accuracy, particularly in patients with a lot of FFM. Diverse ethnic groups displayed remarkable differences in BMI and health outcomes, indicating that diverse cut-off values should be considered in different populations [10]. Extra anthropometric measures should also be provided since BMI does not satisfactorily depict fat distribution.

bioelectrical impedance analysis is straightforward to use because it simply takes information on body height and hip circumference. Only in obese men was the BIA positively associated with glucose and insulin concentrations, implying that the BIA and the total FM percent may be beneficial in the prediction of glucose metabolic issues [7].

Our data indicated that in patients <40 and ≥40 years of age, BIA displayed different degrees of correlation with complete blood count and serum biochemical analysis results. Age must be considered during analysis of BIA measurements in conjunction with metabolic and laboratory indicators. As a cheap and practical modality, popularization of BIA can be considered as a useful tool particularly in clinical practice for clinicians dealing with obesity and other metabolic and endocrinological disorders.

As a result, it could be used in daily clinical practice and population studies to measure cardiometabolic risk associated with fat mass as a surrogate marker of inflammation, metabolic dysfunctions, comorbidities, and complications. Furthermore, analysis of the relationship between BIA and metabolic indicators must be carried out separately in different age groups since LM, FM, and body fat percentage may display different features in people <40 and ≥40 years of age.

Chemical components, protein, water, and minerals make up fat-free mass, which do not consume energy on their own [1]. The assumption that the ingredients that constitute FFM have a similar metabolic rate is made when FFM is used as the denominator against which the resting metabolic rate is expressed. This strategy is compromised by the reality that it combines tissues and organs with drastically different metabolic rates.

In spite of their small combined weight, the brain, liver, heart, and kidneys constitute about 60% of the metabolic rate at rest [11]. Aside from the heart, aging has a noteworthy effect impact on the majority of these organs [12,13].

In adults, adiposity is related to inflammatory responses with significant contribution from visceral adipose tissue [4,13]. However, little research has been performed on the effects of the distribution of fat on metabolic and inflammatory risk factors. It would be captivating to note which aspect of fat distribution advances inflammation in obesity which brings about a high risk for cardiovascular disease. The leukocyte count is a practical and simple test that provides useful data. Consequently, establishing a link between leukocyte count and fat distribution, especially in clinical settings, may be valuable [4].

There is a strong link between white blood cells, BMI, and body fat percentage [14]. Obesity was also connected to a considerably higher WBC count in teenagers [15]. Adipose tissue serves both for energy storage and as an endocrine organ [16]. Macrophages penetrate adipose tissue at a higher level when obesity increases, possibly eliciting a pro-inflammatory response [17]. Obesity was found to be the second most common cause of leukocytosis, after smoking [18]. Since inflammation is one of the most common metabolic risk factors, understanding the link between inflammation and adiposity is crucial. Inflammation constitutes a risk factor for ischemic stroke that is free of the degree of atherosclerosis and it is also a predictor of diabetes [19,20].

In the young age group, inflammatory markers have been associated with cardiovascular risk factors such as pulse rate, systolic blood pressure, and plasma levels of fibrinogen and homocysteine [21-23]. Moreover, the WBC count can be used to predict all-cause mortality, especially due to cardiovascular disease [24]. As a result, it would be clinically useful to use a simple test to detect patients at risk in this age group.

Some restrictions of the present study are cross-sectional design, data collected from a single center, and possible impacts of socio-economical factors and ethnicity. The determination of causality is difficult in the observed associations. These limitations must be remembered during the extrapolation of our data to larger populations.

## *Conclusion*

To conclude, BIA is a cheap, practical and non-invasive tool that may provide useful data for the relationship between metabolic indicators, obesity, and complications. This association must be separately analyzed in different age groups and validation of our preliminary findings and documentation of the clinical usefulness of BIA necessitate the implementation of further prospective multicentric trials on larger groups.

***Scientific Responsibility Statement***

*The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.*

***Animal and human rights statement***

*All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.*

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***Conflict of interest***

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